Chinese Agron. J. 6 : 191-199 (1996)
Chinese Society of Agronomy © 1996

Studies on competitive ability of rice and barnyardgrass III. Comparative growth between rice and barnyardgrass

Chwen-Ming Yang
Department of Agronomy, Taiwan Agricultural Research Institute, 189 Chung-Cheng Road, Wufeng, Taichung Hsien, Taiwan (ROC)

Abstract. Barnyardgrass [*Echinochoa crus-galli* (L.) Beauv.] is a common and troublesome weed species found in paddy field and damaging to rice yield in Taiwan (Yang, 1995b). However, there is no information available on growth behavior of barnyardgrass grown together with rice under the current cropping system in Taiwan. Field experiments were therefore carried out at the experimental farm of Taiwan Agricultural Research Institute, Taichung Hsien, to study growth patterns of these two species and the variations in competition. Results showed that plant height of rice (*Oryza sativa* L. cv. Tainung No.67) and barnyardgrass increased rapidly after transplanting in both pure and competed populations and generally barnyardgrass grew faster and taller than rice in either crop. When grown with barnyardgrass, tiller and leaf numbers of rice were lower than the pure stands in both cropping seasons, and *vice versa*. Barnyardgrass was superior to rice in tillering capacity but fell down dramatically than rice in competition with the opponent. Leaf number and leaf area had the similar phenomenon, but rice produced greater leaf area than barnyardgrass in both crops. Rice and barnyardgrass exhibited marked differences in aboveground plant biomass accumulation. Biomass accumulation of rice was higher than of barnyardgrass, and both were reduced in competition of alien species. By growth analyses, it was shown that ratios of culm (CWR), leaf (LWR) and panicle (PWR) weights were not altered by the competition in both plants. More biomass was found allocated to culm than to leaves. LWR was in a decreasing trend after transplanting. CWR of rice reached the maximum at 60 (2nd crop, 1994) and 75 days (1st crop, 1995) after transplanting and then declined rapidly, whereas barnyardgrass maintained its CWR throughout the growth. Therefore, PWR increased linearly in rice and curvilinearly in barnyardgrass. As the results indicated, the two species exhibited differences in growth and competitiveness. Rice had higher leaf area per plant than barnyardgrass that offers an advantage competing for light, but barnyardgrass is superior in plant elongation and early maturity to rice that help its population in competitiveness in the field.

Key words: Rice, Barnyardagrass, Competitive ability, Growth analysis, Biomass.

水稻與稗草競爭關係之探討（三）生長比較

楊純明
臺灣省農業試驗所農藝系

摘要：稗草[*Echinochoa crus-galli* (L.) Beauv.]乃水田常見之雜草，與水稻同步競爭環境自然資源，嚴重干擾水稻的生長及產量表現(Yang, 1995b)。有關水稻與稗草在本省兩期作生產系統下之生長行為及競爭狀態時之差異，目前尚無文獻資訊可供參考，因此本研究特於臺灣省農業試驗所農場(臺中縣霧峰鄉)進行田間試驗，探討、比較此兩植物之生長差異性及競爭反應。參試水稻臺農67號(*Oryza sativa* L. cv. Tainung No.67)栽植密度222,000株/公頃（行株距0.30公尺x 0.15公尺，小區面積2公尺x 7公尺），稗草對照組栽植密度一如水稻者，處理區則以稗草栽植於水稻行間，密度為15株/平方公尺。根據試驗結果，無論係對照或處理區，水稻與稗草在移植至本田後株高迅即增加，而稗草植株在一、二期作均較水稻高且伸長快。在混合族群競爭狀態下，此兩種植物在兩期作的分蘗數及葉片數皆減少。稗草的葉片數與分蘗能力雖然大於水稻，但是在競爭狀況下，其降低幅度高於水稻。兩者之葉面積在到達最高值後便下降，惟兩期作水稻單株葉面積均較稗草多。水稻與稗草地上部生質量的累積曲線呈現明顯差距，水稻之累積量大於稗草，惟兩者皆因競爭而降低。經由生長分析發現，稈重比(CWR)、葉重比(LWR)及穗重比(PWR)都不因競爭關係造成顯著差異，而生質量分佈於稈部多於葉部。兩植物之葉重比自移植後即呈下降趨勢，水稻之稈重比在到達高峰後（二期作約需60天，一期作約需75天）迅速減少，稗草之稈重比則持續維持。水稻之穗重比自抽穗後即呈線性增加，稗草抽穗早於水稻，穗重比以曲線趨勢和緩增加。試驗顯示，水稻與稗草具有不同的生長表現及競爭能力，水稻單株葉面積高於稗草，在光照競爭上較具優勢，有利於生質量的生成與蓄積；稗草植株伸長快而早熟，能在水田迅速建立族群，提升其競爭力。

關鍵語：水稻、稗草、競爭能力、生長分析、生質量。

INTRODUCTION

Annual weeds compete directly with many cereals such as wheat, barley, sorghum, and rice. Expense for weed management becomes a major concern in crop production (Radosevich 1987). Weed management is more and more expensive because of increasing costs of herbicides, equipment, fuel, and labor. This manifests the importance of crop-weed competition study.

Barnyardgrass is a common weed species found in paddy field and is considered to be one of the most competitive weeds damaging rice yield in Taiwan. Yang (1995b) pointed out that growth of rice was reduced when more than 3 plants per meter of row of barnyardgrass occurred in the same habitat of rice. Season-long competition of barnyardgrass at the density of 11 plants per meter of row can reduce rice yield more than 50% in both First and Second crops. However, little research has been conducted on comparative growth behavior of these two plants species, especilly under two crops system in Taiwan.

Numerous experiments uncovered that the magnitude of weed competition effects varies according to crop and weed density (Buchanan and Burns 1971a, Coble et al. 1981, Oliver et al. 1979, Smith 1968, 1974, Yang 1995a, 1995b), weed species (Buchanan and Burns 1971b, Orwick and Schreiber 1979), and duration of competition (Buchanan et al. 1980, Burnside 1979, Oliver et al. 1979). Aldrich (1986, 1987) further suggested

that light competition may be the source of the earliest effects on crop yield. Pike et al. (1990) demonstrated that canopy diameter and sunlit leaf area of *Datura stramonium* and *Xanthium* strumarium accounted for yield loss of soybean in a soybean-weed competition modeling. Peanut yield was reduced when canopy overtopped by the broadleaf weeds (Barbour and Bridges 1995). Barnyardgrass generally grows faster and taller than rice under field growing conditions, and hence more competitive in intercepting solar radiation.

On the other hand, growth and reproduction of barnyardgrass were suppressed by rice when grown together in the paddy field (Yang 1995a). Dry weights of leaves, culms and panicles were decreased by the competition of rice during the growing period. Apparently, barnyardgrass and rice compete each other on the limited natural resources when grown in the same habitat. As barnyardgrass is a strong intruder and competitor in the paddy field, information on comparative growth analysis is needed and would improve the understanding of morphological and developmental differences of the plants and help in developing management strategies controlling the weeds (Ball et al. 1995, Wall 1995). Such data are also needed in the development of simulation models for prediction of weed competition in rice production.

The objectives of this study were to compare plant growth and development of rice with barnyardgrass in the two crops system in Taiwan. Comparisons made included (a) plant elongation, (b) tillers and leaves development , (c) leaf area expansion, and (d) biomass partitioning patterns of different plant parts for each species.

MATERIALS AND METHODS

Field experiments over two crops were conducted at the experimental farm of Taiwan Agricultural Research Institute (TARI), Wufeng, Taichung Hsien, on a loam soil. Caryopses of barnyardgrass were hand-collected from the experimental farm during the spring of 1994 and stored in -20°C before used. Both rice and barnyardgrass were seeded simutaneously and were transplanted to paddy field, one plant per hill. The control plots (pure stands) were planted to a density of 222,000 plants/ ha (0.30 m x 0.15 m) on 9 August 1994 (Second crop) and 8 March 1995 (First crop). For competed plots, seedlings of barnyardgrass were transplanted between rice rows three days after rice transplanting in a density of 15 plants/m^2, and were replanted a week later to ensure a good establishment. Weeds other than barnyardgrass were removed by hand regularly for clean plot maintenance. Recommended fertilizer and pest control practices were followed to both species.

Six plants of rice and barnyardgrass from each replication were sampled periodically to determine the growth characters. Plant height was measured by a ruler from the surface to the toppest point. Tiller and leaf numbers were counted and leaf area was measured using an area meter (model LI-3000A, Li-Cor Corp., USA). The aboveground plant parts were divided into leaves, culm (sheath plus stem), and panicle, and were weighed separately after oven-dried at 80°C for 72 h.

Growth analysis was conducted to describe the response of plant growth over time. Leaf area ratio (LAR) and culm (CWR), leaf (LWR) and panicle (PWR) weight ratios were determined on a per plant basis according to the following formulae:

LAR= LA/PW (cm /g)
CWR= CW/PW (g/g)
LWR= LW/PW (g/g)
PWR= PaW/PW (g/g)

where LA is leaf area, and CW, LW, PaW and PW are dry weights of culms, leaves, panicles and whole plant, respectively. Weight ratios were expressed as a percentage of total plant biomass to account for biomass partitioning.

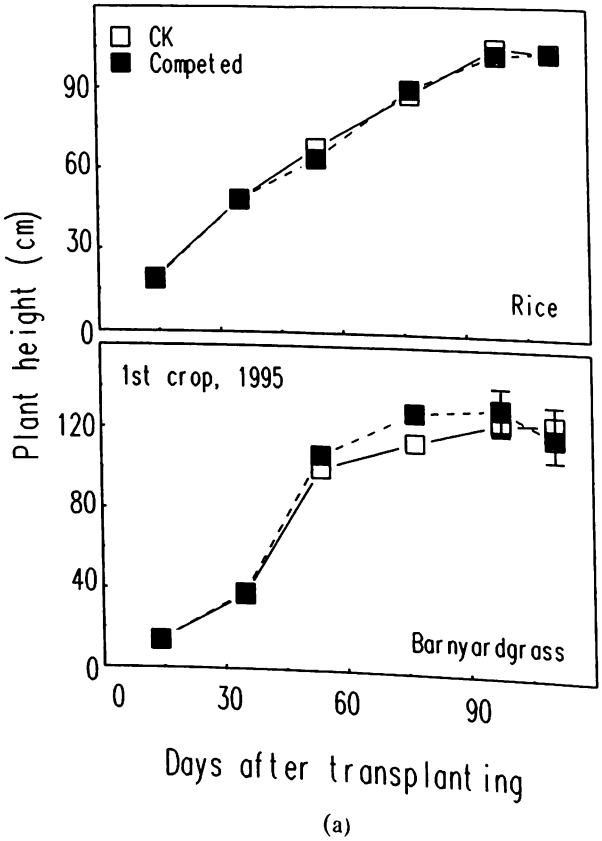
A complete randomized design with four replications was arranged and individual plots were 2 m (6 rows with 0.30 m apart) by 7 m (plant dis-

tance of 0.15 m). Analysis of variance was conducted and the standard error was calculated for statistics.

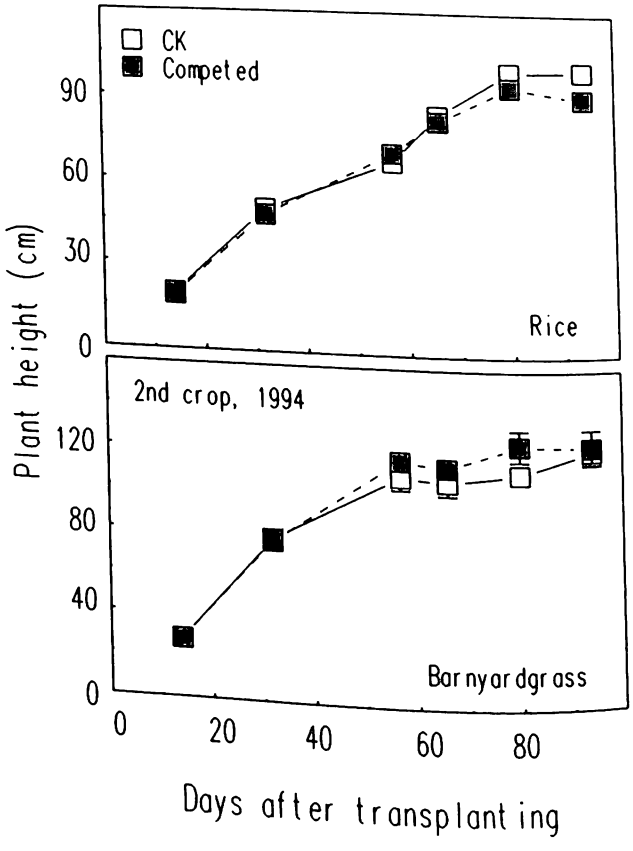
RESULTS AND DISCUSSION

Plant height of rice increased rapidly after transplanting in both pure and competed populations (Fig. 1a and 1b). As shown that maximum plant height was attained at ca. 80 and 95 days after transplanting for the 2nd and the 1st crops, respectively. In the second crop, however, plant elongation of competed plants was hindered by the competition of barnyardgrass in the later stage. For barnyardgrass, no significant difference was found in plant height between treatments during the two growing periods. As indicated that generally barnyardgrass grew faster and taller than rice in either crop, and similar to rice, barnyardgrass reached its peak approximately at 80 days after transplanting in the 2nd crop and took 95 days for the 1st crop.

When grown with barnyardgrass, tiller and leaf numbers of rice were lower than the pure stands in both cropping seasons (Fig. 2a and 2b). On the other hand, barnyardgrass grown in the mixed populations also had less tillers and leaves. Barnyardgrass was superior to rice in tillering capacity but fell down dramatically than rice in competition with the opponent. Leaf numbers had the similar phenomenon, especially in the later development phase. Leaf area expansion was also reduced by the competition of the foreign plants in rice and barnyardgrass (Fig. 3a and 3b). Rice had greater leaf area than barnyardgrass in both crops. However, leaf area ratio was not varied significantly as leaf area between pure and competed stands in rice and barnyardgrass (Figs.

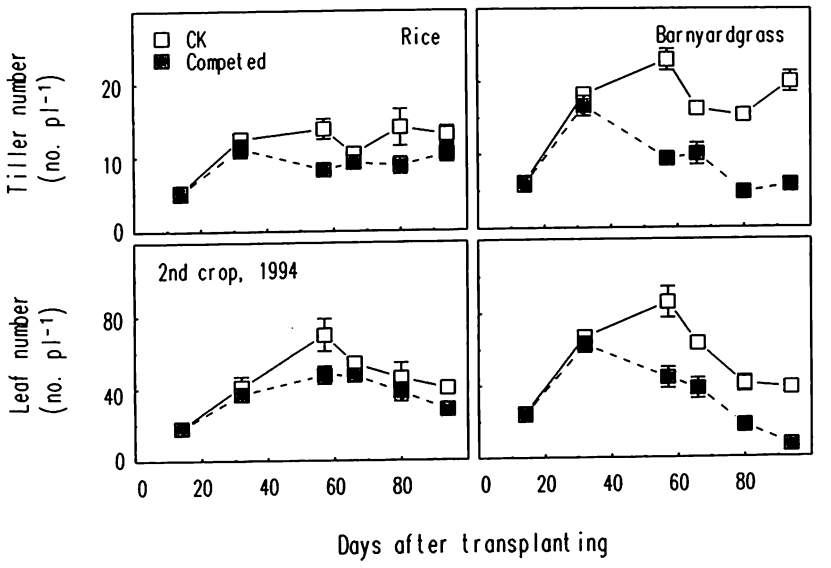


(a)

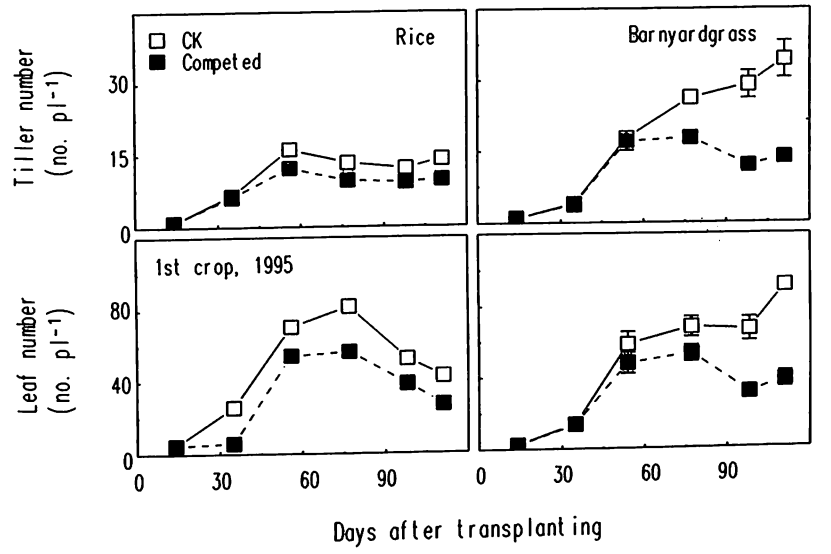


(b)

Fig. 1. Changes of plant height of rice and barnyardgrass during the growing period of (a) the second crop, 1994 and (b) the first crop, 1995. Standard error is included.



(a)

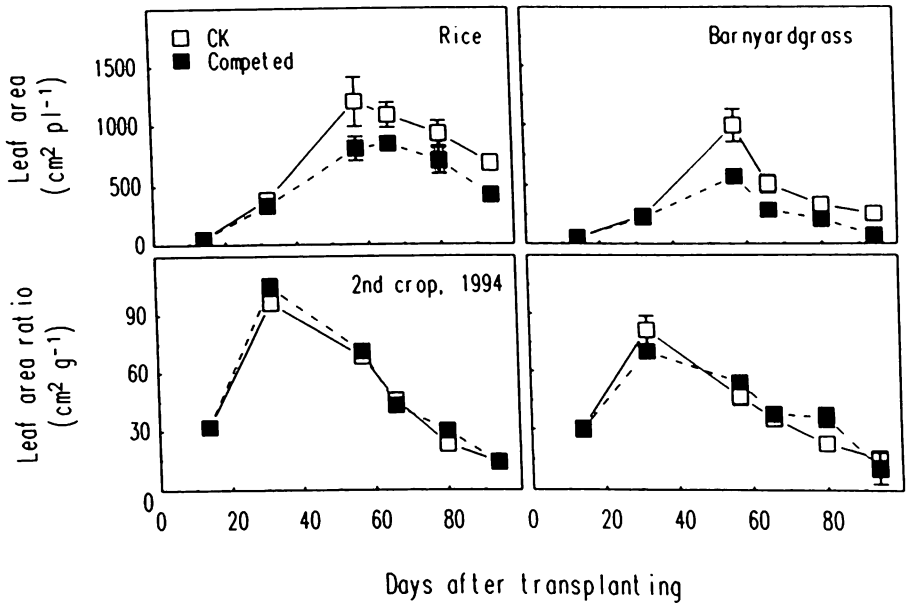


(b)

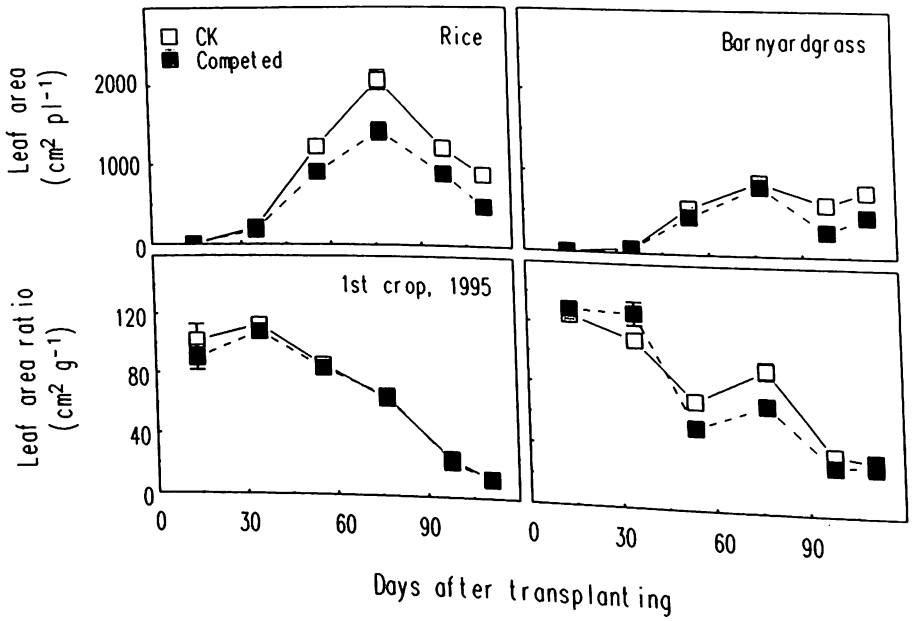
Fig. 2. Changes of tiller and leaf numbers of rice and barnyardgrass during the growing period of (a) the second crop, 1994, (b) the first crop, 1995. Standard error is included.

3a and 3b), implying that competition did not drastically changed photosynthetic (leaf) to nonphotosyn-thetic (aboveground plant parts) tissue ratio.

Rice and barnyardgrass exhibited marked differences in aboveground plant biomass accumulation (Figs. 4a and 4b). As indicated biomass accumulation of rice was higher than of barnyardgrass, and was greater in the 1st than in the 2nd crop. Rice had the maximum plant biomass at harvest, yet barnyardgrass matured earlier and then aged to decrease its weight in the 2nd crop. From the aforementioned results, aboveground plant growth was affected by the competition of



(a)



(b)

Fig. 3. Changes of leaf area and leaf area ratio of rice and barnyardgrass during the growing period of (a) the second crop, 1994 and (b) the first crop, 1995. Standard error is included.

alien species. Thus, aboveground biomass of competed plants, rice or barnyardgrass, were lower than pure stands (Fig. 4a and 4b). As barnyardgrass matured and aged earlier than rice and decreased significantly in aboveground biomass in competed population in the 2nd crop, results suggest that barnyardgrass was less competitive in the 2nd crop than in the 1st crop to rice in the mixed populations.

By further growth analyses, it was shown that ratios of culm weight, leaf weight and panicle weight were not altered by the competition in both species (Fig. 5a and 5b). Figures showed that in both stands leaf weight ratio (LWR) was in a de-

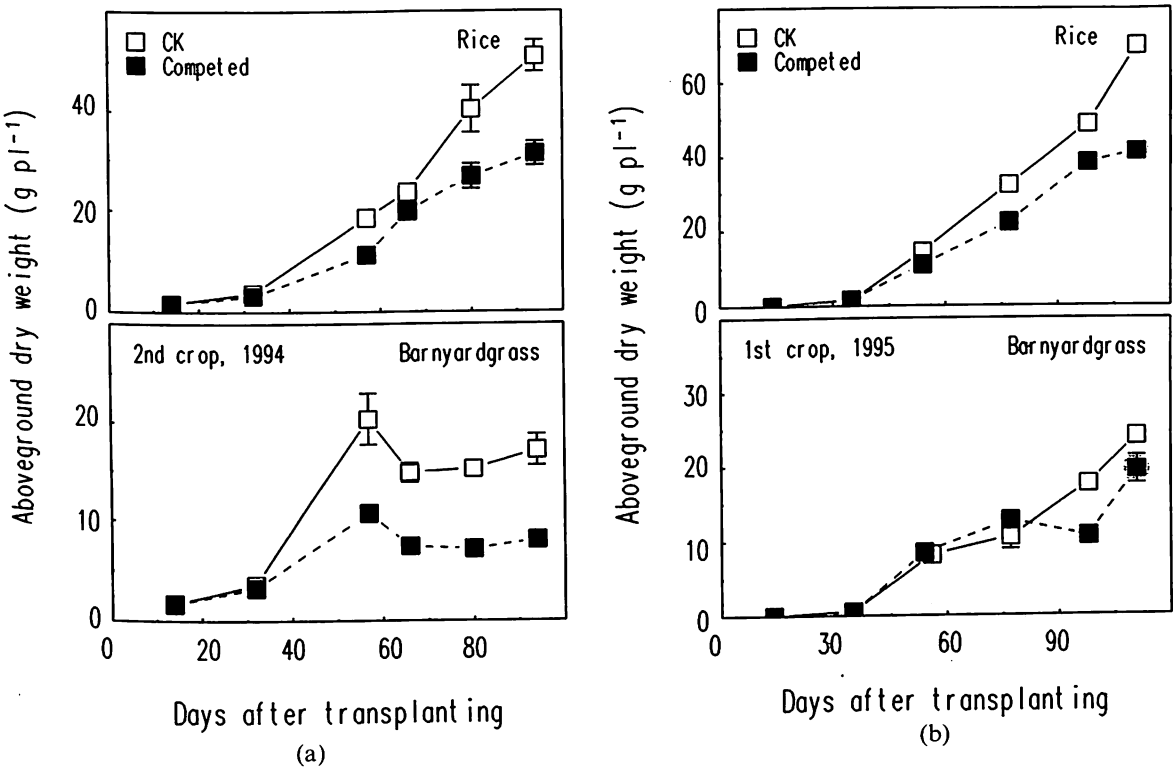


Fig. 4. Changes of aboveground dry weight (leaves + culms + panicles) of rice and barnyardgrass during the growing period of (a) the second crop, 1994 (b) the first crop, 1995. Standard error is included.

creasing trend after transplanting, i.e., biomass allocation to leaf tissue declined since transplanted. Culm weight ratio (CWR) of rice reached the maximum at 60 (2nd crop, 1994) and 75 days (1st crop, 1995) after transplanting and then declined rapidly, whereas barnyardgrass maintained its CWR throughout the growth. Therefore, panicle weight ratio (PWR) increased linearly in rice and curvilinear in barnyardgrass. The PWR data supported the previous result that barnyardgrass matured earlier than rice in either cropping season. Since CWR was in general greater than LWR in both plant species in both crops, it indicated that biomass produced was allocated more to culm than to leaves after transplanting.

As the results indicated, the two species investigated in this study exhibited differences in growth and competitiveness. Plants of barnyardgrass were taller than rice and their elongation did not change significantly when grown together competing with natural resources. Generally rice produced less tillers and leaves than barnyardgrass but these capabilities limited by the competition of opponent plants, particularly in barnyardgrass. Rice had higher leaf area per plant than barnyardgrass in either pure or competed stand that may offer an advantage, relative to barnyardgrass, competing for light in competition.

As two species grown together their biomass production and accumulation were impeded, but barnyardgrass exhibited less competitive in these characteristics. From biomass partitioning patterns, both plants allocated more biomass to culms than to leaves, whereas rice had greater reproductive capacity and obtained higher panicle weight.

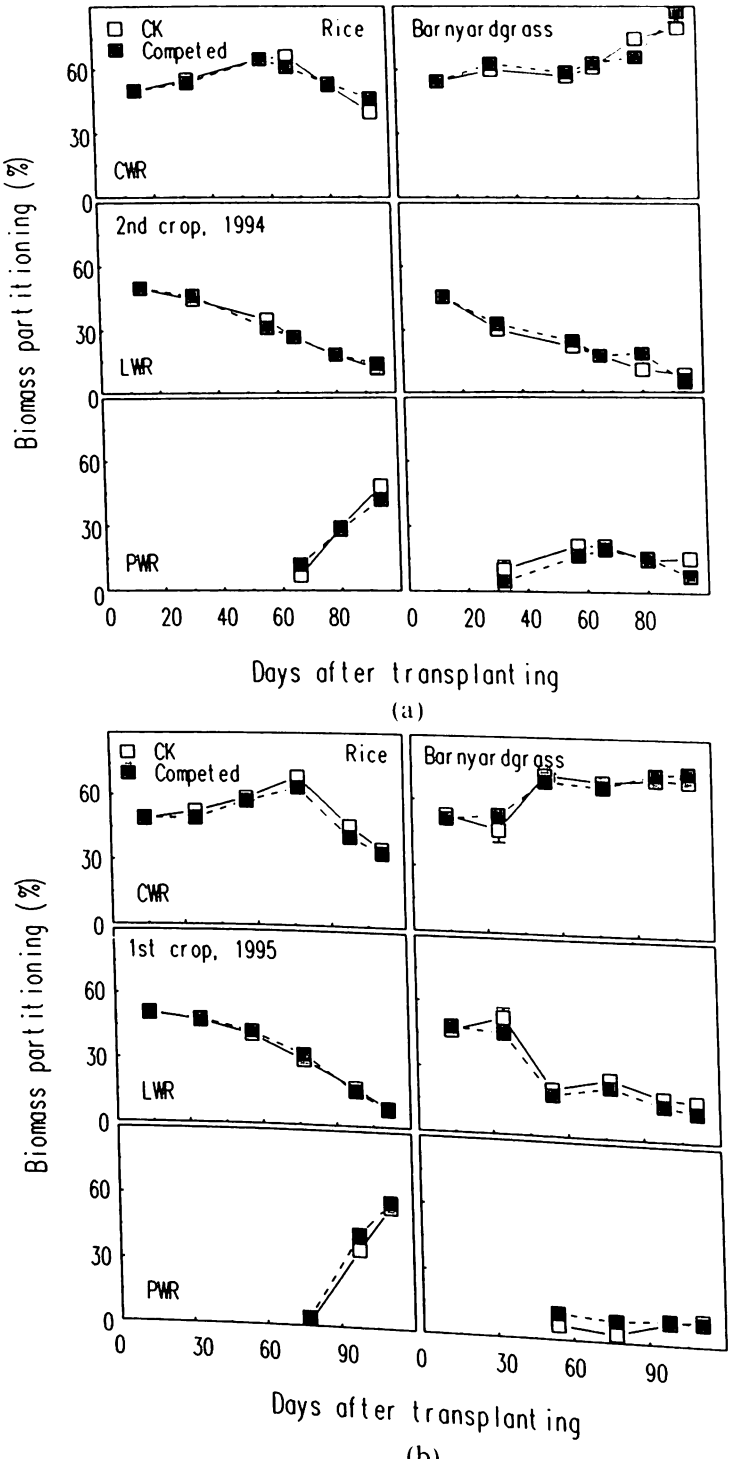


Fig. 5. Changes of ratios of culm (CWR), leaf (LWR) and panicle (PWR) weights of rice and barnyardgrass during the growing period of (a) the second crop, 1994, and (b) the first crop, 1995. Standard error is included.

However, barnyardgrass is superior in plant elongation and early maturity to rice that help its population in competitiveness in the field.

ACKNOWLEDGMENTS

This work was supported by grant from the

National Science Council, the Republic of China (NSC84-2321-B-055-003).

REFERENCES

Aldrich, R.J. (1986) Interference between crops and weeds. In: Allelochemicals: Role in agriculture and forestry. (ed. by Waller, G.R.) pp.300-312. ACS Symposium Series 330. Amer. Chem. Soc., Washington, D.C.

Aldrich, R.J. (1987) Predicting crop yield reductions from weeds. *Weed Technol.* 1:199-206.

Ball, D. A., Klepper, B. and Rydrych, D. J. (1995) Comparative above-ground development rates for several annual grass weeds and cereal grains. *Weed Sci.* 43:410-416.

Barbour, J. C. and Bridges, D. C. (1995) A model of competition for light between peanut (*Arachis hypogaea*) and broadleaf weeds. *Weed Sci.* 43:247-257.

Buchanan, G. A. and Burns, E. R. (1971a) Weed competition in cotton. I. Sicklepod and tall morningglory. *Weed Sci.* 19: 576-579.

Buchanan, G. A. and Burns, E. R. (1971b) Weed competition in corn. II. Cocklebur and redroot pigweed. *Weed Sci.* 19: 580-582.

Buchanan, G. A., Street, J. E. and Crowley, R. H. (1980) Influence of time of planting and distance from cotton (*Gossypium hirsutum*) row of pitted morningglory (*Ipomoea lacunosa*), prickly sida (*Sida spinosa*), and redroot pigweed (*Amaranthus retroflexus*) on competiveness with cotton. *Weed Sci.* 27:568-572.

Burnside, O. C. 1979. Soybean (*Glycine max*) growth as affected by weed removal, cultivar, and row spacing. *Weed Sci.* 27: 562-564.

Coble, H. D., Williams, F. M. and Ritter, R. L. (1981) Common ragweed (*Ambrosia artemisifolia*) interference in soybeans (*Glycine max*). *Weed Sci.* 29:339-342.

Oliver, L. R. (1979) Influence of soybean (*Glycine max*) planting date on velvetleaf (*Abutilon theophrasti*) competition. *Weed Sci.* 27:183-188.

Orwick, P. L. and Schreiber, M. M. (1979) Interference of redroot pigweed (*Amaranthus retroflexus*) and robust foxtail (*Setaria viridis* var. robustaalba or var. robusta-purpurea) in soybean (*Glycine max*). *Weed Sci.* 27:665-674.

Pike, D. R., Stoller, E. W. and Wax. L. M. (1990) Modeling soybean growth and canopy apportionment in weed-soybean (*Glycine max*) competition. *Weed Sci.* 38:522-527.

Radosevich, S. R. (1987) Methods to study interactions among crops and weeds. *Weed Technol.* 1:190-198.

Smith, R. J., Jr. (1968) Weed competition in rice. *Weed Sci.* 16: 252-255.

Smith, R. J., Jr. (1974) Competition of barnyardgrass with rice cultivars. *Weed Sci.* 22:423-426.

Wall, D. A. (1995) Comparative analysis of three cruciferous weeds: growth, development, and competitiveness. *Weed Sci.* 43:75-80.

Yang, C.-M. (1995a) Studies on competitive ability of rice and barnyardgrass. I. Suppressing effect of rice on barnyardgrass. *Weed Sci. Bull.* 16:55-62.

Yang, C.-M. (1995b) Studies on competitive ability of rice and barnyardgrass. II. Effect of barnyardgrass density on growth and yield of rice. *Chinese Agron. J.* 5:375-381.

Received February12, 1996 and accepted March 19, 1996

Edited by Ching Huei Kao

Corresponding author: Chwen-Ming Yang (tel: 04-3302301, fax: 04-3302806)